The Relationship Between Resting Heart Rate Variability and Music Listening Preferences

An Undergraduate Research Thesis

Presented in partial fulfillment of the requirements for graduation with research distinction in Psychology in the undergraduate College of Arts & Sciences at The Ohio State University.

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November, 2018

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Abstract

Listening to music can influence brain regions that both perform executive functions and maintain overall well-being. When it comes to listening to music on a daily basis, it can be categorized into three main groups, including cognitive/ intellectual, emotional, and background listening. Interestingly, higher resting high frequency heart rate variability (HF-HRV) is associated with better executive brain function and thus, both cognitive and emotional regulation, in addition to well-being. While previous studies have examined the impact of music on resting HF-HRV, no study has examined the association between one's resting HF-HRV and their music listening tendencies. Therefore, the current study examined this direct correlation. In a sample of 79 undergraduate participants, resting HF-HRV was collected during a 5-minute resting baseline period. Participants then completed a questionnaire that examined one's varying music listening preferences in the three previously mentioned categories. Results showed that a greater tendency to listen to music was significantly associated with higher resting HF-HRV ($r = .264$, $p = .019$), especially in a cognitive way ($r = .274$, $p = .015$). These correlations remained significant while controlling for age, sex, ethnicity, body mass index, and respiration (cognitive: $r = .290$, $p = .014$; total: $r = .240$, $p = .042$). Overall, my results suggest that resting HF-HRV can predict the general tendency to listen to music, especially in a cognitive manner. Importantly, I propose that HF-HRV may represent the underlying psychophysiological pathway linking music and health.

Acknowledgments

I would like to thank Dr. Julian F. Thayer for giving me the opportunity to join the lab as a research assistant so many years ago and for fostering a lab that encourages young researchers to grow and thrive. I would like to thank Dr. DeWayne P. Williams for the endless opportunities he has provided me, the patience and mentorship, and the love and passion for research he has instilled in me. I thank Michael Smith for agreeing to serve on my committee, and I thank Dr. Jen Cheavens for her humor and mentorship during the 2 semester long thesis course. I would like to thank Geoff Green for allowing me to use data from his music study to help with my thesis. I would like to thank all of the grad students and undergrad research assistants in the psychophysiology lab who helped run this study and make my thesis possible. I thank the Department of Psychology and the College of Arts and Sciences for the opportunity to have this undergrad experience and the funding support to work on my project over summer. I would like to thank all of my music professors who have helped foster and grow my love of music, which in turn sparked the idea for this thesis project. Finally, I would like to thank my amazing parents, friends, and family for their constant love and support throughout my research endeavors. Special thanks goes to my sister Shireen, whose hard work and care for her research has always inspired me in my own endeavors.

Introduction

1.1 Synopsis

Research has shown that passively listening to music is associated with increased activity in prefrontal brain regions that are also responsible for self-regulation and maintain overall health and well-being (e.g., cognitive and emotional regulation; Brown, Martinez, & Parsons, 2004). Resting high frequency heart rate variability (HF-HRV) serves as an index of prefrontal brain activity and is associated with better self-regulation (e.g., cognitive and emotion regulation) and overall health (Thayer, Ahs, Fredrikson, Sollers III, and Wager, 2012). While previous studies have examined the impact of music on HF-HRV (e.g., Tan, Ozdemir, Temiz, and Celik, 2015), no study has examined the association between one's resting HF-HRV and their music listening tendencies; therefore, the current study examined this direct correlation.

1.2 Music Listening, Health, and Prefrontal Brain Activation

Music is fundamental to the human experience, and common in today's environment (Kurdi and Gasti, 2017). Music can be understood and appreciated by anyone, and is capable of providing a relaxing and positive stimulus for mood change and stress reduction (Tan et al., 2015). Music has many physical and psychological effects that have been used to promote health in individuals for many years (Kurdi and Gasti, 2017). Music therapy specifically has been proven to have numerous health benefits and studies have consistently shown the positive effect that music can have on one's physical and mental state (Hanser and Thompson, 1994; Tan, 2015; Kurdi, 2017). For example, in one experiment involving music therapy strategies on older adults with symptoms of depression and distress, researchers found these techniques to be beneficial at reducing such negative psychological distress (Hanser and Thompson, 1994).

Listening to music is one component of music therapy and has shown to be independently associated with better well-being and health (Kurdi and Gasti, 2017). The listener can hear music and experience a wide range of emotions based on the song choice. This may include things such as nostalgia, euphoria, or grief. As it relates to listening to music on a daily basis, research suggests individuals may do so in one of three main ways, including: (1) cognitive listening; (ii) emotional listening; and (iii) background listening (Vella, 2017). Cognitive music listening would involve activities such as score analyzing, intellectual appreciation for a musician's technique, and a deeper understanding of underlying harmonic structure and note choice. For example, one might listen to music for the sole purpose of understanding its harmonic structure, trying to pick out repeated ideas or patterns played by the soloists, or identifying the key center and scales used in the song. Emotional music listening relates to one's ability to connect with a piece of music in a spiritual way. For example, one might listen to a song for nostalgic reasons, because they associate the song with a particular strong positive or negative memory, or because they can really empathize with the artist and want to fully experience those feelings. Background music listening involves the act of listening to music while performing another task. For instance, listening to music while doing homework, working out at the gym, or talking to friends at a party. Background music listening is the least interactive and is probably the most common among the categories (Vella, 2017).

Importantly, research has shown that music listening can increase prefrontal brain activity that both perform executive functions and maintain overall health and well-being (Brown et al., 2004). Interestingly, resting HF-HRV serves as an index of activity in prefrontal brain regions, and is an index of self-regulation abilities (Thayer et al., 2012).

1.3 Resting Heart Rate Variability as a Physiological Marker of Prefrontal Brain Function

According to the Neurovisceral Integration Model (NIM), the reciprocal activity of cortical (e.g., prefrontal brain regions) and subcortical brain regions (e.g., amygdala) is at the autonomic nervous system (Thayer and Lane, 2000). Cortical activity is reflected in parasympathetic (PNS) activity, whereas subcortical activation is typically associated with increased sympathetic (SNS) activity (Thayer and Lane, 2000). The main nerve of the PNS, the vagus nerve, influences heart changes in milliseconds rather than seconds, as in the SNS (Thayer, Hansen, Johnsen, 2010). Thus, PNS activity is capable of producing rapid changes in heartbeats and thus, HF-HRV is primarily influenced by the vagus and is considered a measure of PNS activity (Thayer and Lane, 2000).

When an individual is healthy and at rest, PNS activity should dominate SNS activity, indicating that PNS is well controlled by prefrontal brain regions and thus, shows better self-regulation both from a mental and physical aspect (Thayer and Lane, 2000; Thayer et al., 2010; Thayer et al., 2012). From a physical perspective, lower resting HF-HRV is associated with increased risk for cardiovascular events (Thayer, 2010), inflammation (Thayer, 2010), and a number of other disease states (Thayer, 2010). From a mental perspective, lower resting HF-HRV is associated with higher anxiety, depression, rumination, and a number of other psychopathologies (Thayer et al., 2012). For example, studies have found lower resting HF-HRV to be associated with lapses in attention, (Williams, Koenig, and Thayer 2016) and more difficulties in emotion regulation (Williams et al 2015).

Given how music listening is associated with health and prefrontal brain activation, it is possible that resting HF-HRV is associated with the way in which individuals listen to music on a daily basis; yet no study has directly examined such an association.

1.4 Existing literature on Heart Rate Variability and Music

When it comes to the relationship between HF-HRV, music, and health, there have been many studies to show that such a correlation exists (e.g., Tan et al., 2015; Ellis and Thayer, 2010). One study examined this correlation further to find that the genre of music one listens to may in fact have an influence on one's HF-HRV (Roque et al., 2013). It was shown that relaxant music such as baroque or classical, as well as stimulant music such as heavy metal, were both associated with lower HF-HRV (Roque et al., 2013). While the Roque and colleagues (2013) examined genres of music, it would be important to understand how resting HF-HRV may be associated with daily music listening in either a cognitive, emotional, and/or background way.

1.5 Present Study

My study aims to consider how one's *general* music listening tendencies (but not preferences) are correlated to their HF-HRV and their overall health and well-being. If resting HF-HRV is associated with executive brain activity and overall health (Thayer et al., 2012), and music listening also has an influence on both similar brain regions and overall health (Brown et al., 2004; Ellis and Thayer; 2010), then resting HF-HRV should be associated with one's music listening tendencies. Based on the prior literature, I hypothesized that higher resting HF-HRV would be correlated to greater music listening in all domains, especially in cognitive and emotional domains.

Methods

2.1 Participants

In this study, we collected data from 79 undergraduate participants at The Ohio State University. Participants' age ranged from 18 to 35, and the mean age was 20.15. We had 42 women and 37 men in our study. Participants received either course credit through The Ohio State University Research Experience Program or $20 for their participation in our study. The Institutional Review Board approved our study and all the participants signed a consent form prior to the start of our experiment. Participants were asked to refrain from smoking, strenuous physical exercise, and caffeine intake prior to six hours before the study.

2.2 Procedure

Participants were asked to refrain from drinking caffeine and participating in strenuous exercise prior to the study. At the start of the study, participants' age, gender, height, and weight were recorded. The experiment took place in a sound proof room equipped with a microphone and a camera for safety purposes. This study ran for 90 minutes on average, and was a small part of a larger study in the lab, which examined at HF-HRV and false memory, among other factors. We brought participants into the lab, introduced them to the study and presented them with a consent form. Following the written consent, we monitored the placement of three electrocardiogram (ECG) leads on the participant's front and back. Once the participant was hooked up to the machine, we collected their baseline resting HF-HRV for 5-minutes. For the duration of the 5-minute resting period, participants were asked to sit and breathe normally while their initial measurements were recorded. We then asked them to fill out a series of questionnaires on MediaLab; these questions included demographics, personality assessments, and their music listening preferences.

2.3 HF-HRV Calculations

Continuous HF-HRV was recorded using a 7-lead ECG at a 1000 Hz sampling rate using a Mindware 2000D (MW2000D) Impedance Cardiograph package. We used Bio-Lab to record the HF-HRV data, and later used Kubios to clean the signals. The leads were placed on (1) beneath the right color bone of the upper chest, (2) near the front left side of the floating rib, and (3) near the front right side of the floating rib. We used the ECG trace to measure the variability between R spikes/ inter-beat intervals in milliseconds. IBIs were then analyzed in Kubios HRV Analysis software, yielding calculations for participants' resting HF-HRV (Thayer et al., 2010)

2.4 Uses of Music Inventory

For this study, we used the *Uses of Music Inventory* (see Appendix A) to assess their listening tendencies (Furnham, 2007). This was a self-report questionnaire p2007). The strength of their responses was measured on a five-point Likert-Type scale ranging from -5 "strongly disagree" to 0 "strongly agree" (Furnham, 2007). The first 5 questions ask about emotional music listening, the second 5 questions ask about cognitive music listening, and the final 5 questions ask about background music listening (see Appendix A for full list of questions). Higher scores (scores that approach 0) represent more music listening.

2.5 Statistical Analysis

Statistics were completed in SPSS software. Zero-order correlations were used to assess the direct correlation between resting HF-HRV and all music variables (emotional, cognitive, background, and total). Non-parametric (Spearman's Rho) correlations were also examined to control for issues of non-normal distributions. Partial r correlations were also conducted controlling for age, gender, respiration, weight, height, BMI, and ethnicity. All tests were two-tailed.

Results

Of the 88 participants who originally participated, nine participants were excluded from the final analyses due to missing or incomplete data. This left us with a total of 79 participants (42 female; median age = 20.15, SD = 2.65; mean BMI = 23.81, SD = 5.09). Table 1 shows demographic information for all participants in the sample (n = 79).

Table 1

		Age	Ethnicity	BMI	Respiration	B_lnHF
N	Valid	79	78	78	79	79
	Missing	0	1	1	0	0
Mean		20.15	2.21	23.81	.236812	6.718845
Std. Deviation		2.651	1.273	5.089	.0719931	.9099607
Minimum		18	1	16	.1500	4.5697
Maximum		35	5	46	.3984	8.7555

Zero-order correlation results showed a significant relationship between resting HF-HRV and both cognitive (r = .274, *p* = .015; Figure 1) and total (r = .264, *p* = .019; Figure 2) music listening. There was no significant correlation between resting HF-HRV and emotional (r = .151, *p* = .184; Figure 3) or background (r = .117, *p* = .303; Figure 4) music listening. All zero-order correlations are shown in Table 2.

Table 2						
		B_lnHF	Emotional Music Listening	Cognitive Music Listening	Background Music Listening	Total Music Listening
B_lnHF	Pearson Correlation	-				
Emotional Music Listening	Pearson Correlation	0.151	-			
Cognitive Music Listening	Pearson Correlation	.274*	0.197	-		
Background Music Listening	Pearson Correlation	0.117	.250*	0.205	-	
Total Music Listening	Pearson Correlation	.264*	.691**	.689**	.694**	-

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Note: This table shows zero order correlation coefficients between baseline-resting high frequency heart rate variability (B_lnHF) and all music listening variables.

Spearman's Rho correlations also showed a significant association between resting HF-HRV and both cognitive (r = 0.298, p = .008) and total (r = 0.238, p = .035) music listening. There was no significant correlation between resting HF-HRV and emotional (r = 0.166, p = .144) or background (r = 0.073, p = .523). All Spearman's Rho correlations are shown in Table 3.

Table 3							
			B_lnHF	Emotional Music Listening	Cognitive Music Listening	Background Music Listening	Total Music Listening
Spearman's rho	B_lnHF	Correlation Coefficient	1.000				
	Emotional Music Listening	Correlation Coefficient	0.166	1.000			
	Cognitive Music Listening	Correlation Coefficient	.298**	0.197	1.000		
	Background Music Listening	Correlation Coefficient	0.073	.225*	0.207	1.000	
	Total Music Listening	Correlation Coefficient	.238*	.693**	.676**	.672**	1.000

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Note: This table shows non-parametric correlation coefficients between baseline-resting high frequency heart rate variability (B_lnHF) and all music listening variables.

After controlling for age, respiration, BMI, gender, and ethnicity, resting HF-HRV and cognitive music listening had a significant correlation (r = 0.289*, p* = .014), in addition to resting HF-HRV and total music listening (r = 0.240*, p* = .042). There was no significant correlation between resting HF-HRV and emotional music listening (r = 0.113*, p* = .347) or between resting HF-HRV and background music listening (r = 0.101*, p* = .400) was found. All Partial r correlations are shown in Table 4.

Table 4

Control Variables			B_lnHF	Emotional Music Listening	Cognitive Music Listening	Background Music Listening	Total Music Listening
Age & EthCODE & Gender & BMI & Respiration	B_lnHF	Correlation	-				
	Emotional Music Listening	Correlation	0.113	-			
	Cognitive Music Listening	Correlation	0.289	0.261	-		
	Background Music Listening	Correlation	0.101	0.280	0.213	-	
	Total Music Listening	Correlation	0.240	0.707	0.708	0.707	-

Note: This table shows partial r correlation coefficients between baseline-resting high frequency heart rate variability (B_lnHF) and all music listening variables.

Discussion

Music listening has been shown to influence the same brain regions involved in self-regulation (Brown et al., 2004), and HF-HRV indexes the activity of these brain regions at a resting state (Thayer et al., 2010) and thus, is an index of self-regulation abilities. My novel results showed that more music listening on a daily basis was significantly correlated with higher resting HF-HRV. Subscale results showed that greater cognitive music listening was more significantly correlated with higher resting HF-HRV than emotional and background music listening. Overall, my results support prior work, and further suggests that resting HF-HRV can predict the general tendency to listen to music, especially in a cognitive manner.

3.1 Implications

Previous studies have repeatedly shown HF-HRV to be related to self-regulatory *abilities* (Thayer and Lane 2000). However, little work has shown HF-HRV to be associated with self-regulatory *motivations*. This study is one of the few to explore this relationship; it showed that HF-HRV can predict one's motivation to engage in self-regulatory behavior on a daily basis, which in our case is cognitive music listening or just overall music listening.

Music listening can impact on prefrontal brain activity (Brown et al., 2004), and the scope of the impact can depend on the type of listening and the frequency of the listening (Kurdi 2017). Our study supports this notion, as more music listening is associated with higher resting HF-HRV, and index of greater prefrontal brain activity. Therefore, long term or daily music listening may have an impact on HF-HRV, and potentially health (Ellis and Thayer, 2010). However, additional research would be necessary in order to support this claim. One study in support of this idea showed higher HF-HRV with repeated exposure to music (Iwanaga et al., 2005).

I propose that resting HF-HRV, as an index of self-regulatory abilities, may impact one's motivation to listen to more music. Subsequently, this overall greater music listening, particularly in a cognitive way, may further impact one's HF-HRV via the impact that it has on prefrontal brain activity. Overall, the relationship between resting HF-HRV and music listening tendencies may be bidirectional, and future studies should work to better understand this relationship.

3.2 Limitations and Future Directions

My study is correlational and thus, I cannot specify directionality. However as previously mentioned, there may be a reciprocal relationship between resting HF-HRV and music listening tendencies, however future work should use longitudinal data in working to understand the causational relationship between these variables.

Since our study consisted of all college aged students, there could have been a third variable influence on our results. One potential theory is that college aged students don't have as much free time to listen to music for cognitive purposes and thus, my results may highlight a specific type of student. Therefore, future studies should work to examine these results in varying age ranges.

One's biological sex can have an impact on their resting HF-HRV (Zhang, 2007). Additionally, males and females may listen to music in different ways simply due to societal restrictions (Koskoff, 2000). For example, females are much more likely to engage in and report emotional experiences and feelings (such as emotional music listening) than their male counterparts (Simpson, 2004). While my study was underpowered to do so, future studies should aim to separate data by sexes.

Finally, similar to sex, resting HF-HRV is also different based on ethnicity (Choi et al., 2006; Hill et al., 2015). Although my study controlled for age, sex, and ethnicity, future studies should understand how these variables may impact the association between resting HF-HRV and music listening tendencies. Importantly, the association for subscales may differ as a function of such variables.

3.3 Conclusions

Overall, our study showed us that daily music listening, specifically cognitive music listening, is associated with resting HF-HRV. This could have serious implications in the field of music therapy, as these professionals aim to help better the health of their patients through musical interventions. Potentially, HF-HRV may be the mechanism underlying better health from music listening and therapy (Ellis and Thayer, 2010). Overall, resting HF-HRV and music listening tendencies likely influence one another, and our data support the adaptive nature of listening to music, especially in a cognitive way, on health.

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Appendix A

1. Listening to music really affects my mood
2. I am not very nostalgic when I listen to old songs
   I used to listen to (R)
3. Whenever I want to feel happy I listen to a happy song
4. When I listen to sad songs I feel very emotional
5. Almost every memory I have is associated with a particular song
6. I often enjoy analysing complex musical compositions
7. I seldom like a song unless I admire the technique of the musicians
8. I don't enjoy listening to pop music because it's very primitive
9. Rather than relaxing, when I listen to music I like
   to concentrate on it
10. Listening to music is an intellectual experience for me
11. I enjoy listening to music while I work
12. Music is very distracting so whenever I study I need
    to have silence (R)
13. If I don't listen to music while I'm doing something,
    I often get bored
14. I enjoy listening to music in social events
15. I often feel very lonely if I don't listen to music

Figure 1: Cognitive Music Listening and HRV

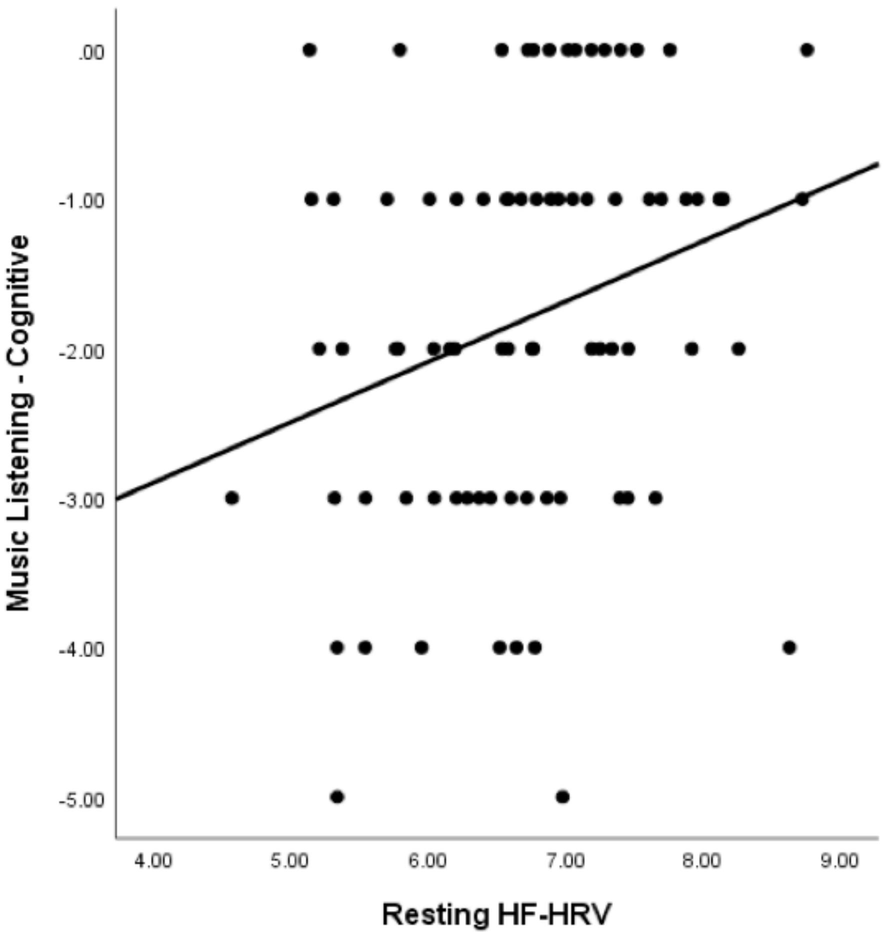

Figure 2: Total Music Listening and HRV

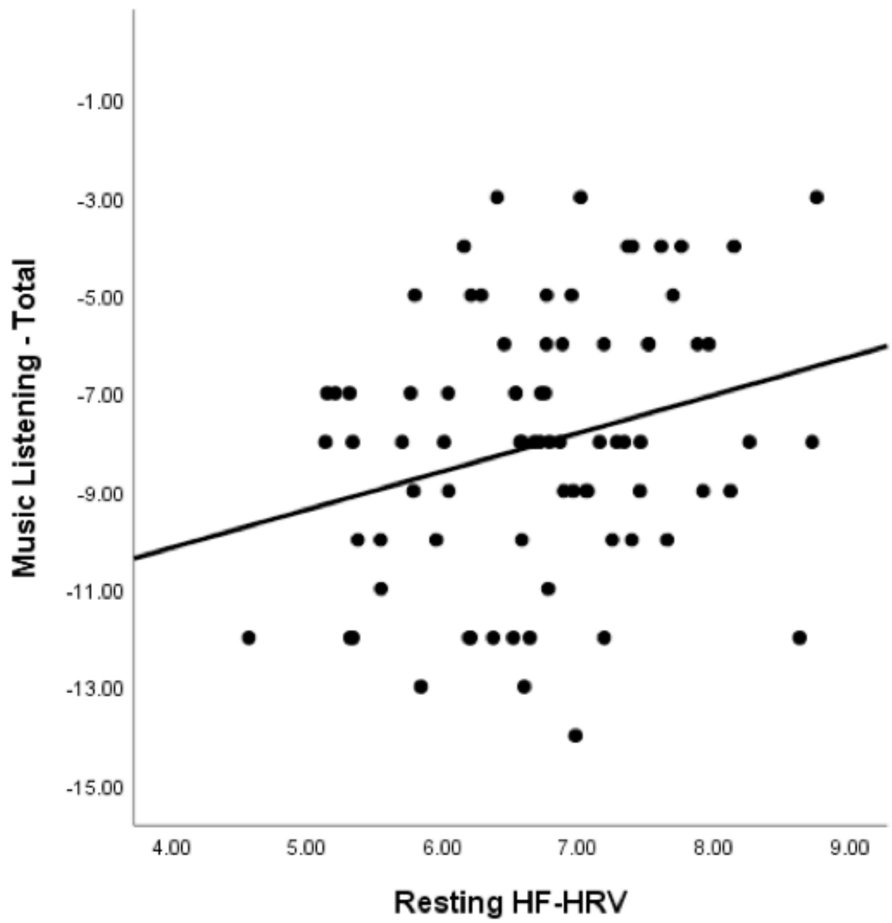

Figure 3: Emotional Music Listening and HRV

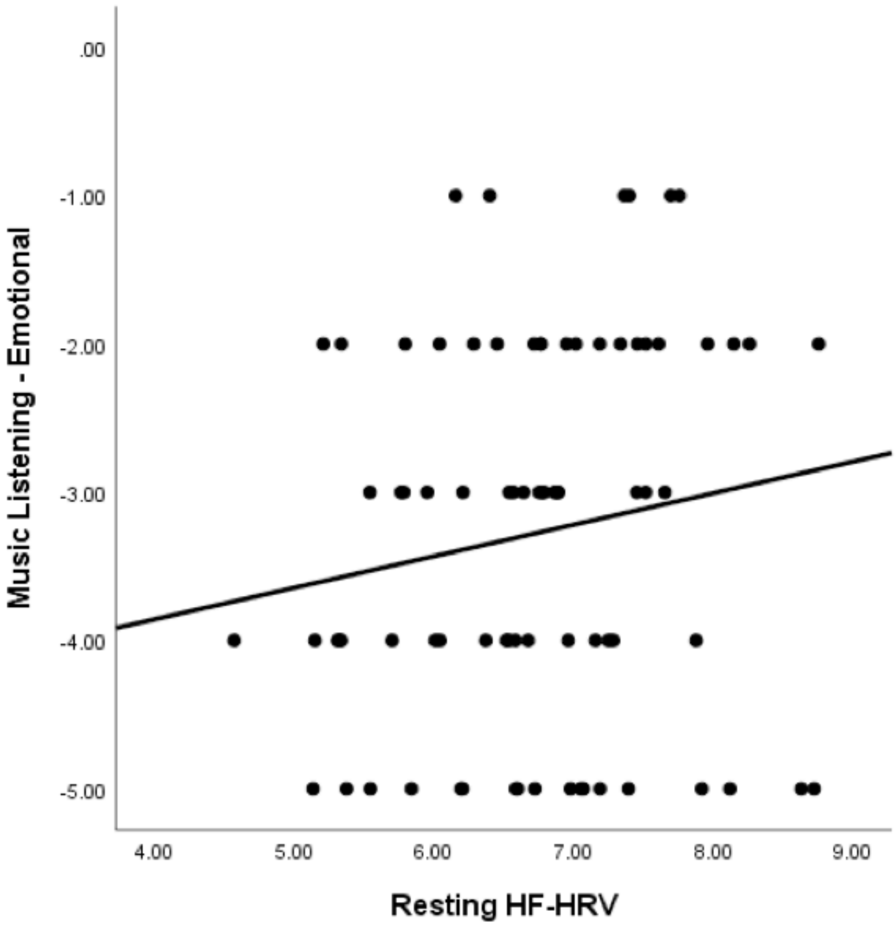

Figure 4: Background Music Listening and HRV